

Review of data on persistence of SARS-CoV-2 in the environment and potential infection risk

Audience: PHE internal /NERVTAG review

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Note: SARS-CoV-2 virus has previously been known as 2019-nCoV and WN-CoV.

Question: How long does SARS-CoV-2 persist on surfaces and remain infectious?

Answer: Until specific data emerge, it is reasonable to extrapolate from knowledge for other coronaviruses and other enveloped RNA viruses. We know for these other viruses that the duration that the virus can persist in the environment, in an infectious form, will depend on multiple factors that will vary and may be context-specific; for example: the amount of virus shed by different individuals; the nature of the contaminant/excreta containing the virus (e.g. thick mucus containing large numbers of virus particles); humidity; temperature; UV light exposure; the material onto which the virus has been deposited (plastic, wood, metal, soft furnishing etc.); and activities that may remove virus and therefore decrease the overall infectious burden over time, including cleaning and inadvertent removal of virus (e.g. when clothes brush past a contaminated surface).

Laboratory-based studies

A study that examined the environmental stability of MERS-CoV (van Doremalen *et al*, 2013) looked to see how long recoverable virus could be recovered from steel and solid plastic, under laboratory conditions. High titre (10^6 TCID₅₀) droplets of MERS-CoV were inoculated onto plastic or metal surfaces. By 48 hours there had been a $>4 \log_{10}$ (99.99%) decrease in virus titre and by 72 hours no infectious virus was detectable (Appendix 1). This was notably longer than influenza A virus stability under the same conditions.

A study investigating the stability of high titre (10^7 TCID₅₀) droplets of SARS-CoV dried onto a plastic surface at “room temperature” also detected a 4-log drop (99.99%) in viral titre at 48 hours (Appendix 2, Figure part (a)). Virus remained detectable at low titres up to 6 days (Rabenau *et al*, 2005). Of note, the starting titre of virus (10^6 - 10^7 TCID₅₀) used in the experiments by van Doremalen *et al* and Rabenau *et al* may well be significantly higher than would be expected to be shed into the environment by an infectious person. Hence, the residual quantity of virus after decay is likely to be significantly less in a real-world setting. Additionally, the infectivity of low titre virus in cell culture is not directly comparable to its infectivity in the human upper respiratory tract where physico-chemical barriers (e.g. mucous, low pH) will limit virus infectivity.

In another study, SARS-CoV was reported to remain viable for up to five days on smooth plastic surfaces at 22 to 25°C and 40 to 50% relative humidity “with only 1 \log_{10} loss in titre” (Chan *et al*, 2011). However, the addition of foetal calf serum (a virus-stabilising laboratory reagent) limits comparison to virus shed in human respiratory secretions. High titres (10^7 TCID₅₀) of SARS-CoV artificially inoculated into respiratory samples decreased in infectivity by >4 logs after 3 days, remaining detectable at low titres up to 5 days at room temperature (Appendix 3); however, these were samples kept in closed specimen containers and would not have been subject to ventilation and drying encountered under ‘room air’ conditions (Lai *et al*, CID 2015). A recent review of 22 studies (Kampf *et al*, 2020) on environmental persistence of human coronaviruses concluded that duration of persistence varied depending on the surface material. Indeed, Duan *et al*. found that SARS-CoV appeared to remain more infectious on glass than other household materials although

residual infectivity was not directly quantified. Even at a relatively high concentration of virus particles, when droplets were applied to paper the virus could not be recovered 24 hours after drying (Lai *et al.*, CID 2005). These findings are consistent with the relatively extensive literature on influenza virus survival which consistently identifies that virus survival is more prolonged on hard, non-porous, surfaces.

Clinical studies

Environmental sampling from hospital rooms of MERS-CoV-infected patients (Bin *et al.*, CID 2016) reported that viral RNA was detected from environmental samples 5 days after the resident patient's upper respiratory tract (URT) sample was negative for viral RNA. This finding should be interpreted with some caution as the presence of viral RNA does not equate to existence of infectious virus. In one patient's room in this study, "virus culture" from an environmental sample was reported to be positive 24-48 hours after a negative URT virus detection. However, the methodology used in this study does not allow us to distinguish virus input versus that amplified in culture, as has also been noted by international correspondence (Oh M-D, CID 2016)

Question: How long does SARS-CoV-2 persist in airborne droplets/aerosols and remain infectious?

Answer: Whilst large droplets (>10-20um) can fall to ground with gravity, aerosols and droplet nuclei (<5-10um) may remain suspended in the air for prolonged time (Tellier *et al.*, 2019). Preventing transmission of infectious virus in aerosols requires FFP3 respiratory protection. Surgical masks are generally deemed as adequate protection from large droplet/fomite transmission.

The mode of transmission of SARS-CoV-2 is unknown; particularly, its ability to transmit via aerosols. The ability of SARS-CoV-2 virus to remain viable in aerosols over time is also unknown.

The primary mode of SARS-CoV and MERS-CoV transmission is generally thought to be direct mucous membrane contact with infectious respiratory droplets and/or through exposure to fomites. SARS cases occurred primarily in persons with close contact with infected persons in health care and household settings (WHO, 2003). However, airborne/aerosol transmission may be possible, particularly following aerosol-generating procedures or events. The duration of time that virus can remain viable in aerosols is unknown but viability is likely to decline over time and be dependent on factors such as temperature, humidity and constituents of respiratory secretions. Van Doremalen *et al.* demonstrated that MERS-CoV retained viability in aerosols at 40% humidity far better than influenza virus under the same conditions (7% versus 95% reduction in viability).

Comments and interim recommendations

Taken together, at the current time in this evolving outbreak, and taking account of the uncertainties and limited scientific data, we recommend that the following principles are taken into consideration:

1. The infection risk from environmental contamination will decline over time, particularly under conditions conducive to ventilation and drying. An approximately 4 log reduction is seen in MERS-CoV and SARS-CoV in a laboratory environment over 48 hours, which represents a 99.99% reduction in virus titre. A 4-log reduction in viral titre is defined by European Standards (EN 14476) to be sufficient for surface disinfection (ECHA 2017).
2. Rates of virus decline will be dependent on a number of factors, named above.
3. Laboratory settings where information about viability is measured are useful but do not provide an exact model for typical community settings. Environmental factors affecting viability should be considered in the risk assessment including air circulation, humidity and temperature.
4. Caution should be taken direct extrapolation of data on the ability of virus to persist under artificial conditions (such as within a closed container or in the presence of stabilising

agents), to a real-world setting. Scientific data to support the ability of MERS-CoV/SARS-CoV to remain viable for prolonged duration in the environment is lacking. However, data does indicate that MERS-CoV/SARS-CoV are more environmentally stable than influenza virus or HCoV-229E.

5. It would be reasonable to assume that in many typical community settings potentially contaminated by a symptomatic infected individual there would be a significant decline in infectious virus over 24-48 hours after the individual left the area or recovered.
6. Level of contamination is likely to be higher in healthcare settings because of more severe cases and aerosol generating procedures that may increase shedding of virus onto environmental surfaces. The presence of more hard surfaces in healthcare settings versus soft furnishings in community environments will also affect virus persistence.

The selection of cut-off point should be taken using consideration of the environmental factors described above and the acceptable residual risk. Taking all of these points into consideration, we consider that a practical and precautionary approach would be to use a 48h cut-off for persistence of significant risk in a contaminated community environment, particularly on hard, non-porous surfaces. A 48h threshold does not guarantee a total absence of infectious virus, but we believe the likelihood of fomite transmission would be by then significantly reduced and likely absent.

This is interim advice that may be updated as new information becomes available.

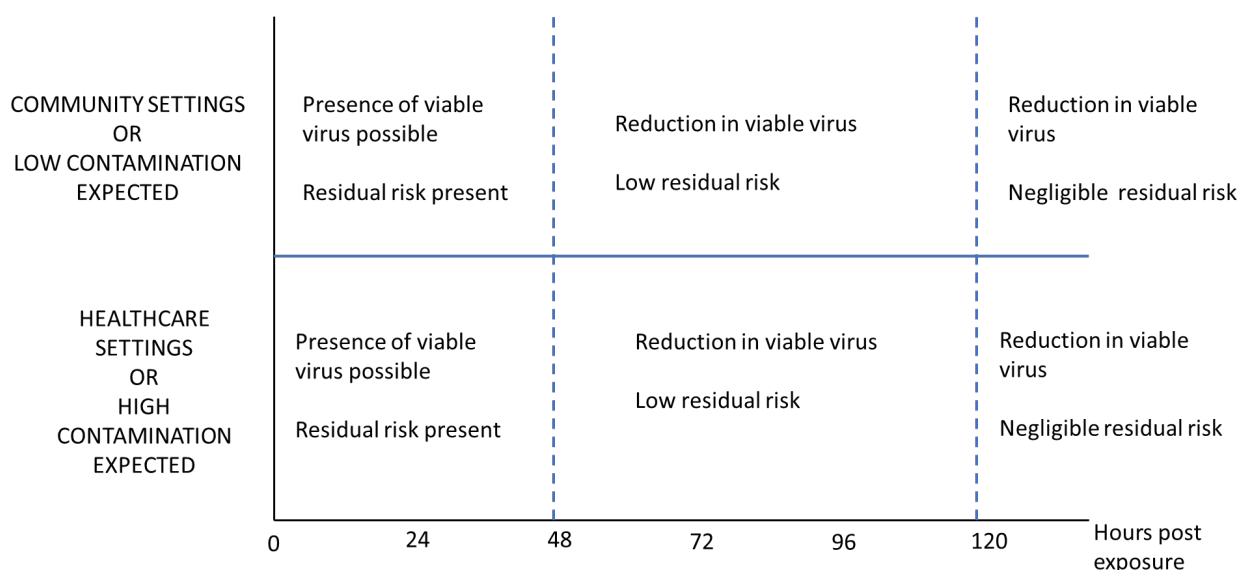


Figure 1. Graphic of likelihood of environmental contamination with infectious virus

Healthcare settings refers to hospital and primary care facilities. Community settings include hotels, shops, homes etc.

High contamination might involve presence of vomit/ diarrhoea/ very symptomatic individuals as well as a function of time spent by infected person in affected area.

Residual risk will be present where appropriate PPE to avoid fomite transmission is not used. A risk assessment of the need for higher level PPE is required which takes into account the likelihood that infectious droplets/aerosols are present. For example, time since infected person was in the area, humidity, temperature, airflows, use of any aerosol generating procedures or cleaning methods. This is addressed further in PHE guidance document: “Decontamination and Cleaning of Environments in the Community and Care Settings”.

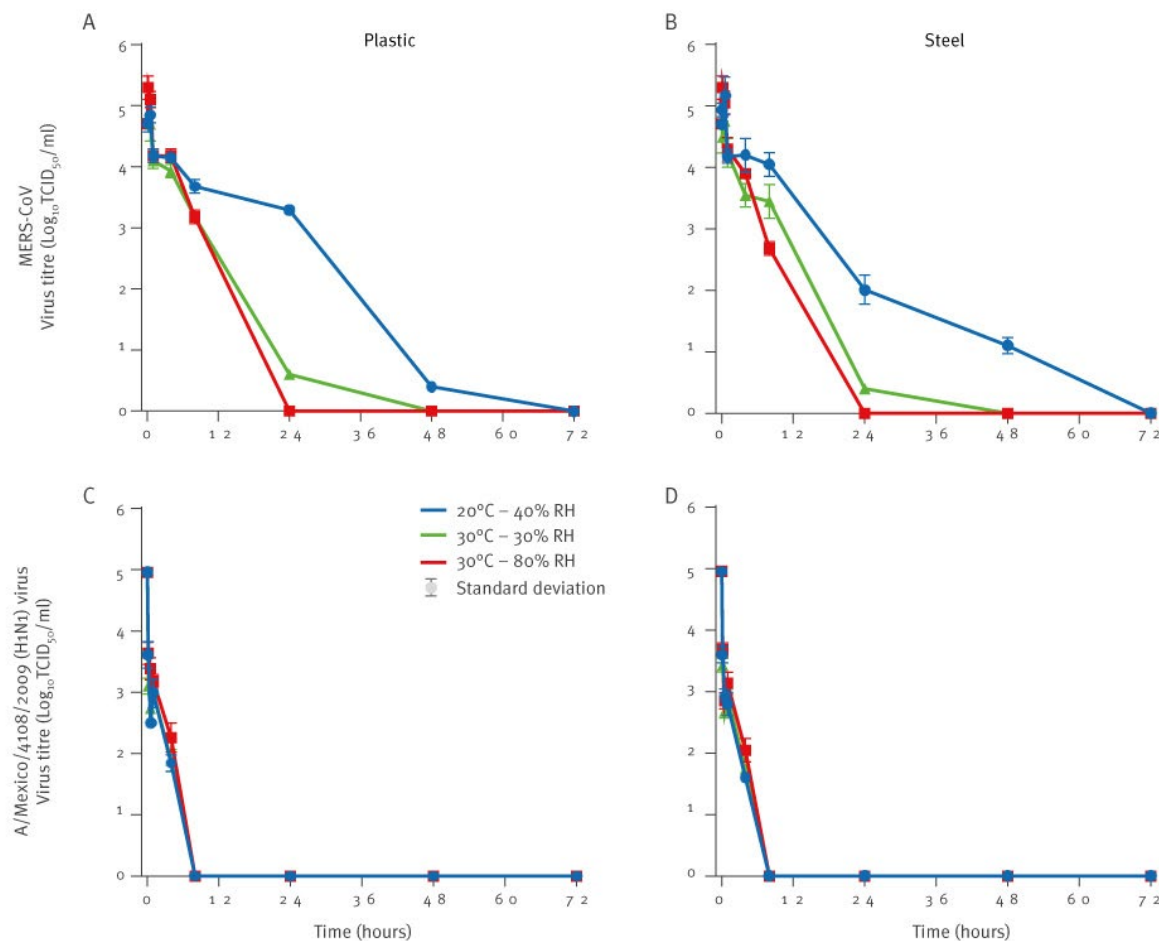
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Appendix 1

FIGURE 1

Viability over time of Middle East respiratory syndrome coronavirus (MERS-CoV) and A/Mexico/4108/2009 (H1N1) virus under different environmental conditions



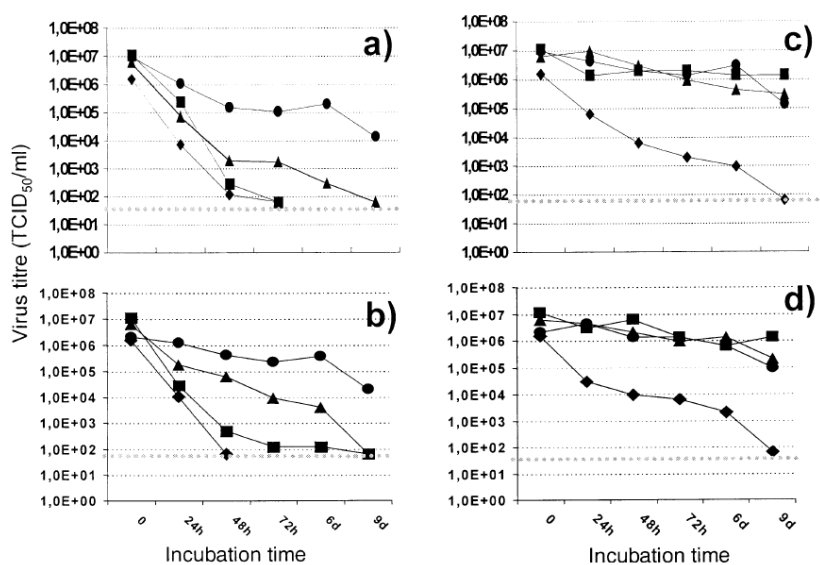
RH: relative humidity; TCID_{50} : tissue culture infective dose 50.

10^6 TCID_{50} of MERS-CoV (isolate HCoV-EMC/2012) (panels A and B) or A/Mexico/4108/2009 (H1N1) virus (panels C and D) was spotted on plastic (panels A and C) or steel (panels B and D) surfaces, incubated at 20°C – 40% RH (blue); 30°C – 30% RH (green) and 30°C – 80% RH (red) and titrated on VeroE6 cells (for MERS-CoV) or Madin-Darby canine kidney (MDCK) cells (for A/Mexico/4108/2009 (H1N1) virus).

Virus decay curves taken from N van Doremalen *et al.* 2013

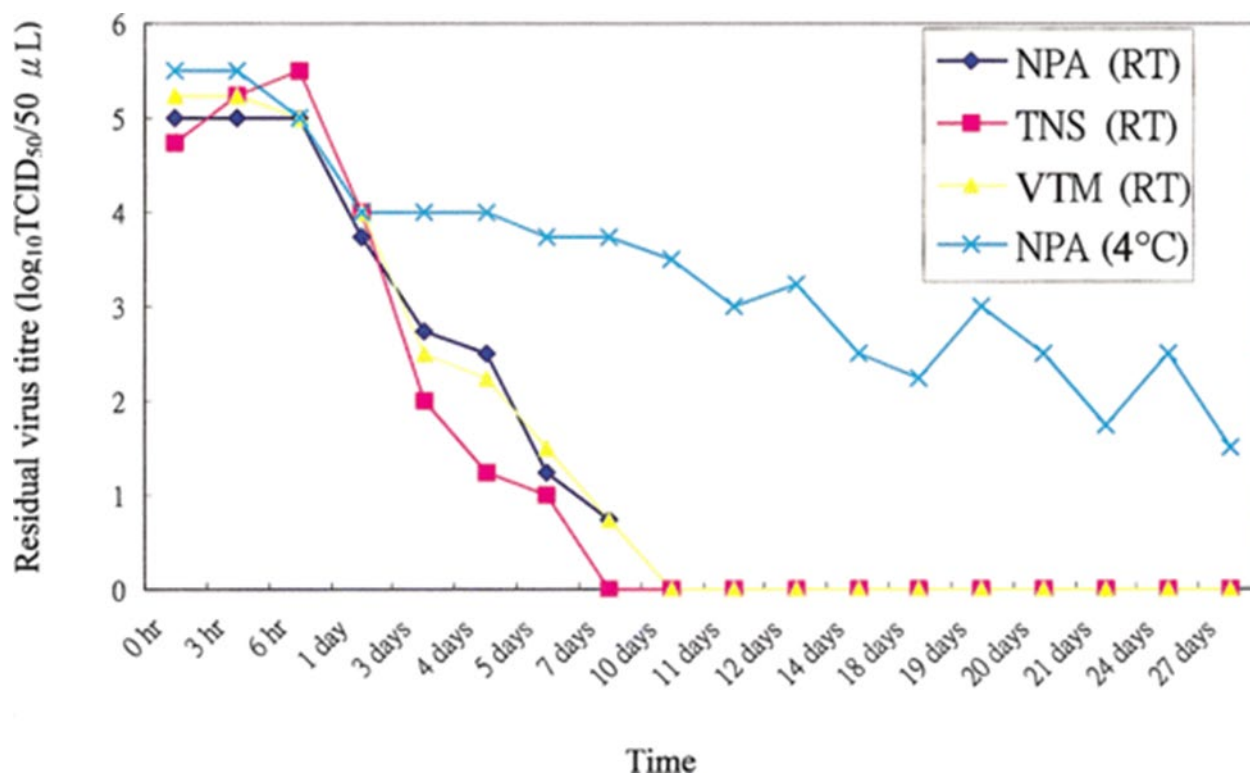
Appendix 2

Fig. 2a-d In vitro stability of SARS-CoV, HCoV-229E, HSV-1 and adenovirus type 3 either in suspension or dried. Infected cell culture supernatants were incubated at RT either in suspension (c, d) or dried on a plastic surface (a, b), in the presence (b, d) or absence (a, c) of 10% FCS. Values are means from three independent experiments. The SD did not exceed 20%. ▲ SARS-CoV (FFM1), ◆ h-CoV (E229), ■ HSV-1, ● adenovirus type 3, detection limit



Appendix 3

Virus decay curves taken from Rabenau *et al.* 2005



Virus decay curve from Lai *et al.* Survival time of 10^7 SARS-CoV spiked into closed containers of nasopharyngeal aspirate (NPA) specimens, throat and nasal swab (TNS) specimens, or viral transport medium (VTM) at room temperature (RT) and at 4°C